WATER AS A BLAST SHOCK SUPPRESSANT

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Introduction

This paper reports MODUK/CESO(N) sponsored empirical investigation of water as a blast shock suppressant on behalf of the Royal Navy. Interestingly the suppression of blast quasi-static pressure (QSP) is being investigated by the US Navy. Blast shock is a concern in the open and blast QSP in a ship's magazine.

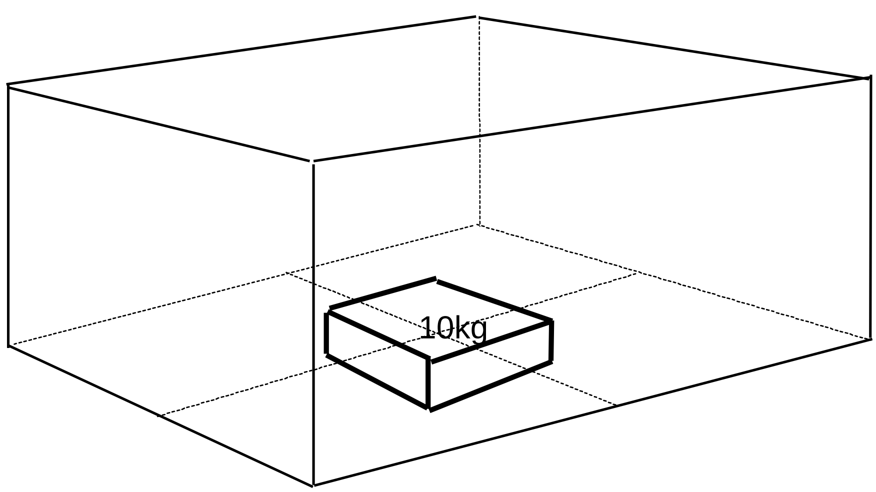
The original idea for blast shock suppression came from two people, Mr John Parkes trading as Dell Explosives in Collinton Dell, Edinburgh and Professor Stephen Salter, Head of Mechanical Engineering Design at the University of Edinburgh. Salter presented some possible applications at the 1994 DDESB Seminar in Miami.

The MODUK investigation was born out of a need to store 10kg of TNT equivalent explosives in a built up area with no distances available for safety purposes.

Outline

A standard test charge of 8.5kg of PE4, equivalent to 10kg of TNT was test detonated tamped by plastic water bags shaped as a cube. 95% blast shock suppression was achieved but there was too much local disruption. Three more shapes of water were tested until there was no local disruption. The further shapes were a half-cylinder, a cube surrounded by a special arrangement of plastic bags to dissipate shock energy internally and a sphere.

The Cube



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The cube shape was achieved using slabs of expanded polystyrene bound together with a plastic tarpaulin fastened with Velcro. Note that all the structural material added nothing to the explosion hazard. The 10kg TNT equivalent chargewas on the ground central to the cube base. The empty cube was filled with many small plastic bags of water. There was about 6 tonnes of water. The blast side-on overpressure recorded was 5% of that recorded by a control test detonation in the open of the same weight and shape of explosive.

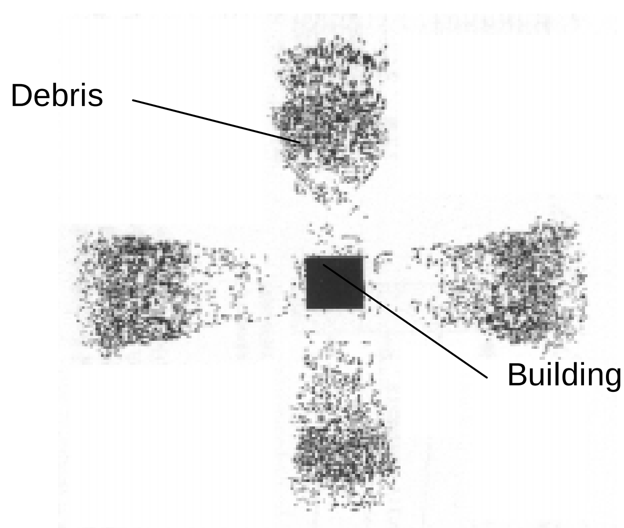
However, the large amount of the local disruption was unacceptable. A very large crater was formed so although the ground shock wasn't measured it would have been enhanced. Cohesive slugs of water flew from the sides of the cube. Each was deduced as weighing about 1 tonne (6 tonnes of water and 6 faces to a cube). The slugs broke into droplets in about 10 metres of flight but within that short distance they would have been destructive.

It was concluded that if the achieved 95% blast shock suppression was to be acceptable to explosive site operations then all the enhanced local disruptive behaviour would have to be at least no worse than that from a detonation in the open and ideally, better. To recap, the unwanted local explosion effects were:

Enhanced Cratering,
Enhanced Ground Shock, and
1 tonne slugs of water.

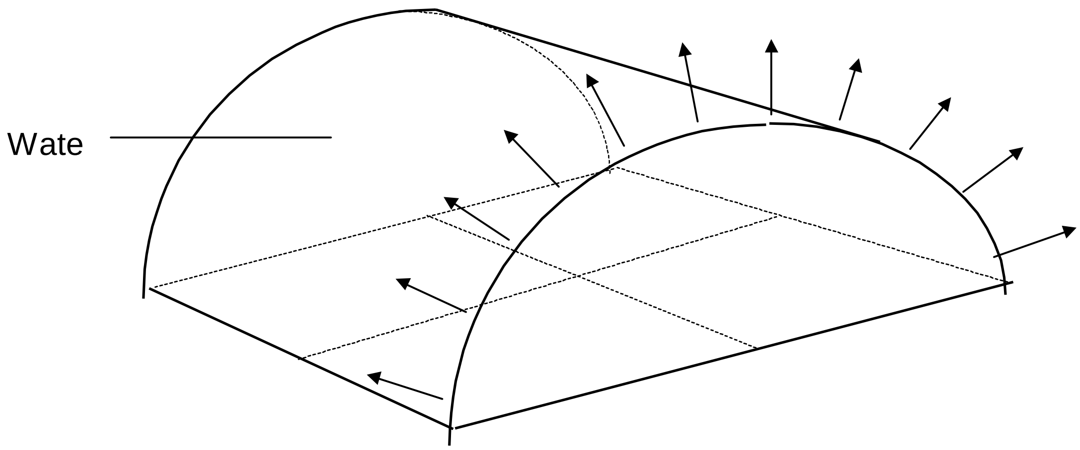
It was decided to removae the water slugs first as these would be the most destructive.

The Half Cylinder



The above diagram shows the debris patterns expected from an explosion of a square building. Note how the debris has flown normal to the surface of the walls with little dispersion. So it is with a cube of water. Water will fly normal to the faces of the cube. All the water from one face would fly as a cohesive slug until cohesion fails and water droplets are formed.

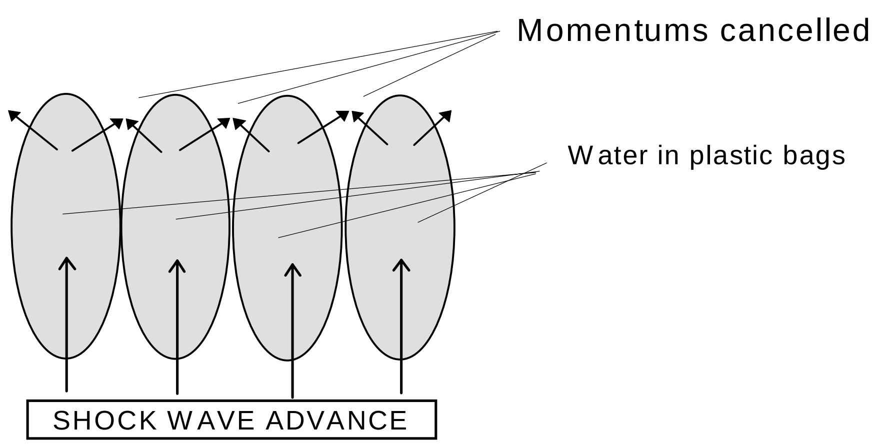
If the water shape was convex then the water would still fly normal to the surface but it would no longer be cohesive as it would be dispersing from the moment it was launched. (Conversely concave shapes will form damaging hypersonic water jets.)



Two trial detonations showed that this was the case. All the water dispersed as aerosol droplets and no cohesive slugs were formed. The final design would have to rely on convex outer surfaces. Blast suppression remained at 95%.

As expected, cratering and ground shock were still bad as the charge was on the ground and heavily tamped with water. Meantime another idea had emerged.

The Special Arrangement of Bags



Salter had had another idea. If the bags were so arranged that they parted slightly away from the source of the blast shock wave, then as the shock passed through them and at the point where the bags parted, the impedance ahead of the shock wave would be higher than to the side. At that point a lot of water would be thrown out sideways from the bags. Water thrown sideways from one bag would meet much the same mass of water travelling at about the same speed coming from the opposite bag and their two opposing momentums would cancel each other out. Energy would be consumed.

This was investigated two dimensionally using 500lb TNT (a charge case of a sea mine). There were three detonations. For two of them the charges were tamped with water bags to achieve blast shock suppression. The third was untamped. The tamping of one of the charges had an outer ring of bags which in plan view looked like the petals of a flower.

The largest crater was from the tamped charge without a ring of bags. The smallest crater was from the tamped charge with a ring of bags. The middle size crater was from the untamped charge.

Clearly Salter's theory works. It reduces cratering and hence ground shock to less than that from an open or unsuppressed detonation.

Blast shock suppression averaged 93%.

The Spherical Shape

The conventinal way to reduce cratering and ground shock is to place the charge off the ground. This was tested in a sphere of water.

There were three detonations, two in water spheres and one unsuppressed with the charge being the same height off the ground as in the spheres. The observations showed that there were no unacceptable local disruptions. Cratering had disappeared and no slugs of water were formed. Blast shock suppression was less than before at 89%. This was because the spherical shape used less water.

The "proof of principle" programme was at an end. Satisfactory design concepts had emerged from the empirical research and development trials to enable an ideal design shape to be concluded.

The Ideal Design Shape

The best shape to suppress blast shock would be a sphere with explosives placed in the middle. To overcome the reduction in the amount of suppression occasioned by a spherical shape needing less water, the sphere should include the special bag arrangement to absorb shock energy internally.

Cost Comparisons

It is interesting to compare costs. Comparing water spheres that give around 90% blast shock suppression against full blast containment using either mobile steel spheres or static reinforced concrete structures, the costs approximate to:

Water £9,000 - Steel £100,000 - Concrete £75,000.

Water cannot give full blast containment but it can achieve around 90% blast shock suppression for roughly 9% of the cost of steel or 12% of the cost of reinforced concrete.

The extra 5-10% blast suppression to achieve full containment would cost roughly an extra £91,000 for steel or £66,000 for reinforced concrete.

The Future

Scientific exploration of the way that water works as a blast shock suppressant is underway at the Royal Military College of Science sponsored by CESO(N).

An early aim will be to determine the relationship between weight of spherical water and weight of explosive so that the degree of blast shock suppression required can be specified without the need for proof firings.

The later aim will be to investigate the relationship between the energy released by an explosion and how it is absorbed both as heat and as a shock wave. Clearly this will have more to do with physical rather than chemical or mechanical properties.